Shuttle Small Payloads Project

Carrier Capabilities

1999

Shuttle Small Payloads Project
NASA Goddard Space Flight Center
http://sspp.gsfc.nasa.gov

The crew of Discovery mission STS-95 participating in a post mission panel discussion in the GSFC auditorium.

The Mission Manager receives crew award from the Commander on behalf of the IEH-3 Hitchhiker team.

The Mission Manager leads crew briefing for the TEAMS Hitchhiker mission on STS-77.

OVERVIEW

The National Aeronautics and Space Administration (NASA) has initiated four carrier programs for accommodating small attached payloads in the Space Shuttle payload bay. These are known as the Get Away Special (GAS), Space Experiment Module (SEM), Hitchhiker-Jr (HH-Jr), and Hitchhiker (HH) programs. These programs are designed to serve NASA's goals of performing earth and space science, fostering and demonstrating new technology, providing low cost access to space, and supporting education initiatives. All four programs are developed and operated by the Goddard Space Flight Center (GSFC) Shuttle Small Payloads Project Office (SSPPO), for the NASA Office of Space Flight, Payload Carriers Program Office, Kennedy Space Center.

The GAS carrier provides limited standard mechanical and electrical interfaces for self-contained experiments. Simple crew control functions may be performed, but power (battery), data recording and sequencing systems, if needed, are provided by the user.

The SEM carrier system is a self-contained assembly of engineered subsystems which function together to provide structural support, power, data storage, and command capabilities for zero-gravity and microgravity experiments, flown as U.S. educational payloads, in the NASA Space Shuttle.

The HH-Jr carrier provides mechanical and electrical interfaces similar to the existing GAS carrier with slightly expanded electrical services, and limited crew monitoring. The HH-Jr payload is operated via crew control and utilizes Orbiter power.

The Hitchhiker program is intended for customers whose space activity requires power, data, or command services. The Hitchhiker system provides for real-time communications between customers in the control center at GSFC and their payloads. It can also provide crew control and display capability, if necessary. Mechanical and electrical interfaces and integration procedures are more complex than those used for GAS.

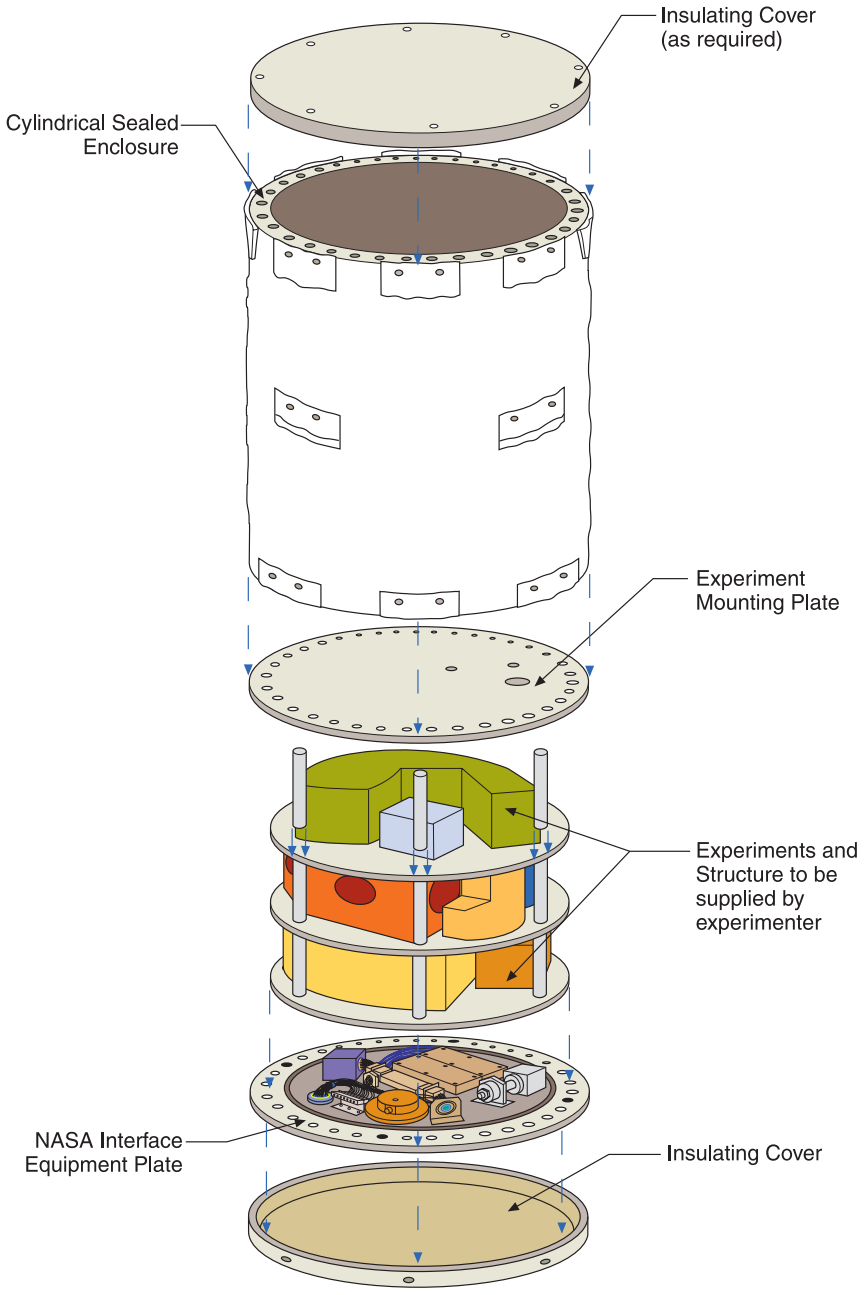
Cross-Bay “GAS Bridge” carries up to twelve canisters.

GAS Program

The GAS Program was initiated in the mid-seventies to provide a diverse user community with extremely low cost access to space. GAS payloads are carried in standard canisters which can be mounted in varied locations on the side of the Shuttle payload bay via a GAS "Adapter Beam Assembly." Up to twelve canisters can also be mounted on the cross-bay "GAS Bridge Assembly" carrier if required by the mission. It is NASA's intention to emphasize the U.S. educational aspects of this program, while continuing to serve the needs of a multidisciplinary community.

GAS Carrier Description

The GAS carrier consists of a canister (5 ft3) which can accommodate customer equipment in a volume of up to 19.75 inches in diameter and 28.25 inches high. The customer equipment can weigh up to 200 lbs. and attaches to the canister top plate. A smaller (2.5 ft3) canister is also available for 60 and 100 lb. payloads.



Exploded View of GAS can

Electrical connection functions via customer supplied cables to the GAS electrical interface on the canister bottom plate. Bumpers on the customer equipment provide lateral support. Provisions are made for insertion of purge gas into the canister and for venting a customer battery box.

Each canister is equipped with an electrical system which has a 25 amp power relay and two, 2 amp signal relays for controlling customer equipment. All canisters connect to a common signal line in the Orbiter which connects to a Payload and General Support Computer (PGSC) in the crew cabin. The crew can individually address up to three relays in each canister, to turn the relays on or off, or determine the state of a relay. All relays can also be simultaneously reset by a master reset command. An optional baro-switch can be used to turn the power relay on during ascent.

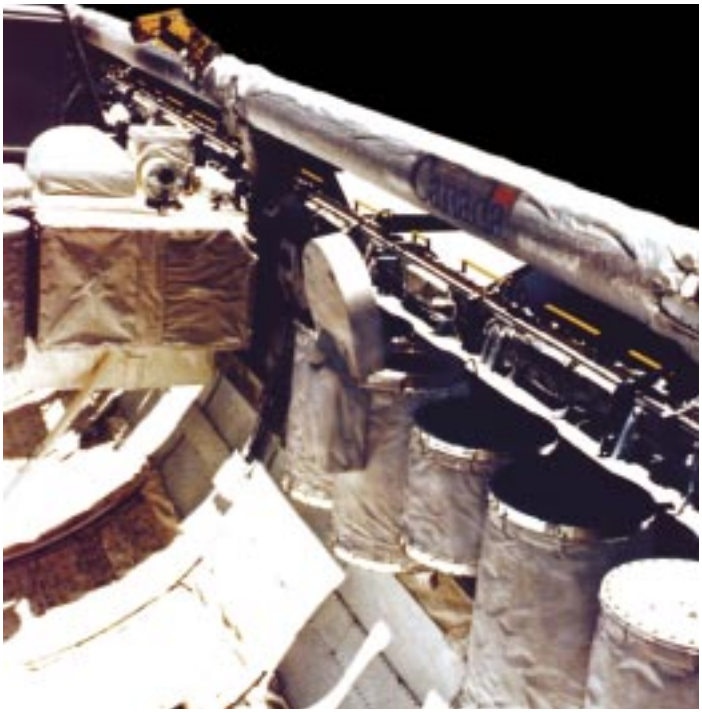
As non-standard services, special top plates may be used with apertures for customer equipment, or mounting small customer items on the top (exposed) surface of the plate is possible. Apertures or exposed hardware significantly impact safety considerations. A motorized pressure door may also be used with the GAS canister to allow

exposure of the customer hardware to the space environment through top plate apertures of up to 15 inches in diameter while providing protection for ascent and descent. Pressure relief valves vent the canister atmosphere during ascent to near vacuum prior to door opening by crew command.

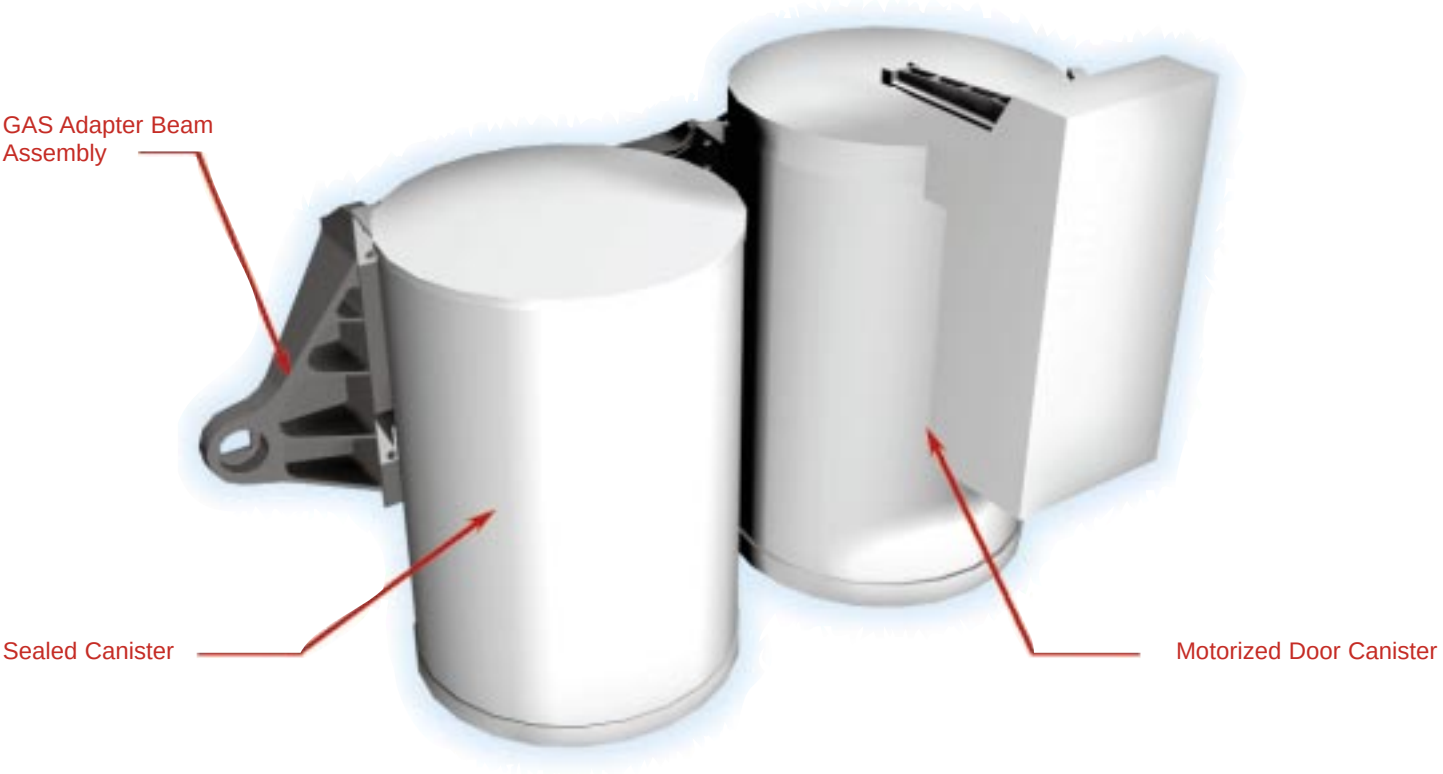
GAS Programmatics

GAS customers apply to NASA Headquarters, Office of Space Flight (Code MO) and, if reimbursable, enclose a deposit. GAS is operated on a first-in, first-out queue system, and can be used by any individual or organization. GAS payloads may be used only for research or education, and not for direct commercial use. As of January 1999, 157 GAS payloads have flown on the Space Shuttle.

SSPPO will provide potential GAS customers with user guide manuals.



Side-mounted GAS payloads on orbit.



Typical side-mount GAS configuration.

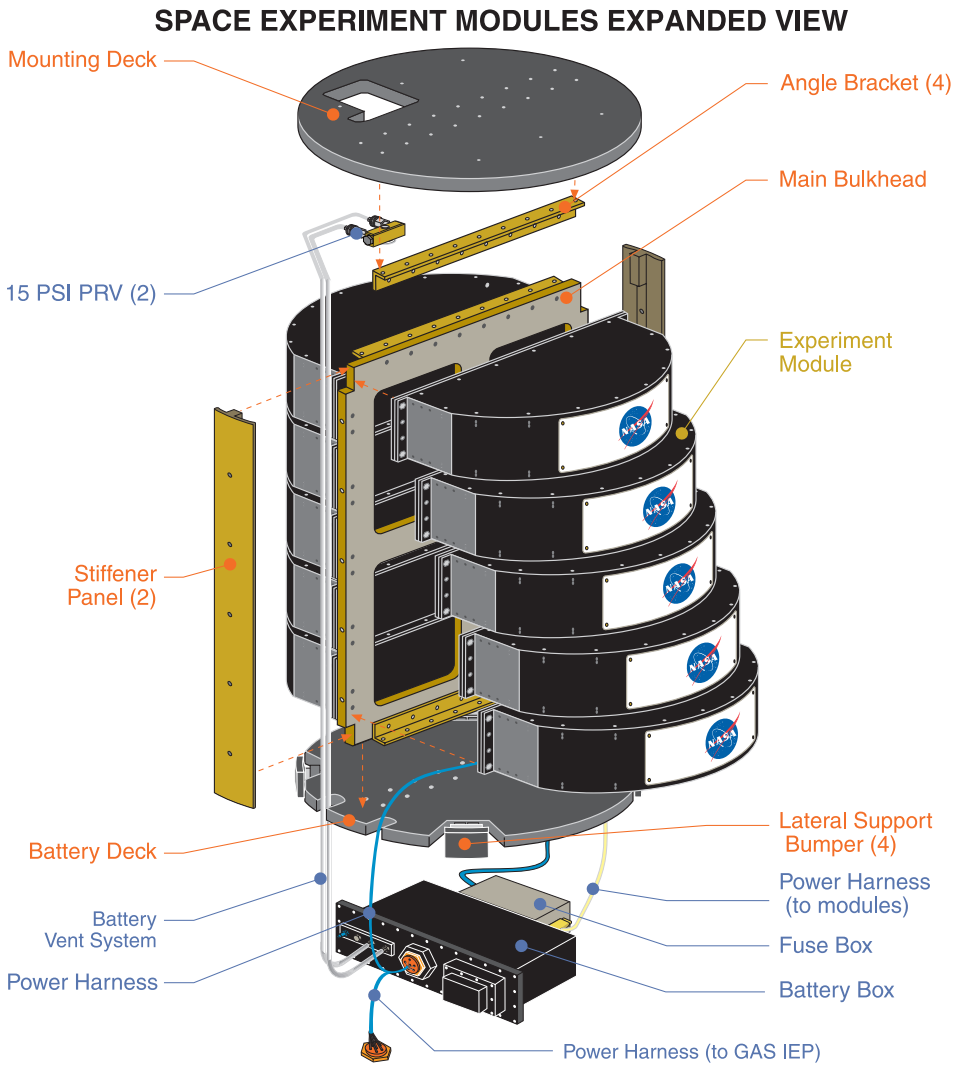
Space Experiment Module (SEM) Program

The Space Experiment Module (SEM) Program is an education initiative sponsored by the NASA Office of Space Flight. The program provides nationwide educational access to space for Kindergarten through University level students. Within the program, NASA provides small containers or modules to students to fly zero-gravity and microgravity experiments on the Space Shuttle. The experiments are created, designed, built, and implemented by students with teacher and/or mentor guidance. Student experiment modules are flown in a "carrier" which resides in the cargo bay of the Space Shuttle. The carrier supplies power to, and the means to control and collect data from each experiment.

Overview

The Space Experiment Module (SEM) carrier system is a self-contained assembly of engineered subsystems which function together to provide structural support, power, experiment command, and data storage capabilities for zero-gravity and microgravity experiments to be flown in the NASA Space Shuttle.

Students may design experiments "on paper" using NASA supplied software and databases. Use of the software is not restricted and can be accessed via the World Wide Web at: http://sspp.gsfc.nasa.gov. The software application helps the experimenter describe the experiment, enter power consumption, part and materials, and time-line, control and command data. The software may be used to analyze the data for SEM compatibility and "post flight" reports.



Expanded view of SEM payload.

The small, enclosed module can contain approximately 300 cubic inches (4.9 L) of experimenter apparatus weighing up to 6 lb. (2.7 Kg.). Experiments may be active (uses carrier-supplied power) or passive (non-powered). They may be contained inside of the modules by one of two methods. The first method of experiment containment uses NASA-provided "Space Capsules" to enclose passive test articles. The Space Capsules are clear, sealable polycarbonate vials 1.0 inch in diameter and 3.0 inches in depth. The second method of experiment containment utilizes the Module Cover as an Experiment Mounting Plate.

The free space available for experiment apparatus in the Module experiment compartment is the "Experiment Envelope." It is a precisely defined volume delineated on the inboard surface of the Experiment Mounting Plate and extends 3.25 inches below the inboard surface of the Mounting Plate.

The modules are powered by one 12 Volt battery independent of the Shuttle's power supply. Each module has an integrated programmable control circuit board, or Module Electronics Unit (MEU), for data sampling and storage. The MEU processes the student-devised flight operations time-line. After installation of the experimenter's equipment, up to 10 modules are housed in a pressurized canister (identical to a GAS canister).

During the early stage of the Shuttle flight, astronauts activate the SEM canister via the PGSC. For active experiments (those using battery power), the MEU's carry out their unique programmed time-line throughout the flight.

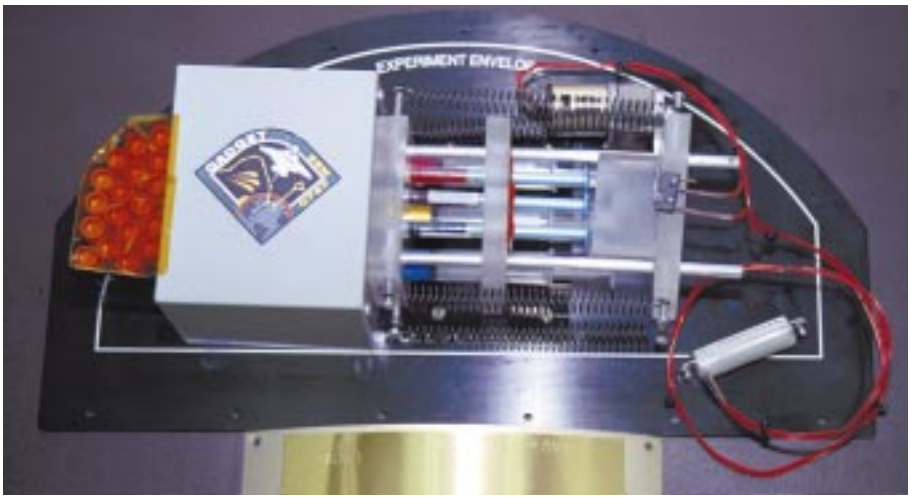
Following Shuttle space flight of the SEM payload, the experiment hardware, the in flight measurement data from the MEU, and a "Certificate of Space Flight" will be returned to the student experimenters. Experimenters are requested to provide a copy to NASA of their post flight data analysis and reports. NASA archives the results and has them available for future experimenters to reference.

SEM's Flight History

The SEM carrier system has flown six times, on STS-80, STS-85, STS-88, STS-91, and STS-95. The system was flown four times in 1998 carrying both passive and active experiments. SEM experiments were on board the historical Shuttle flights with John Glenn and the first assembly flight of the International Space Station. The seventh flight is scheduled to launch in late 1999.

The Mission Manager instructs elementary school students visiting Goddard Space Flight Center in the construction of an experiment module.

Engineers integrate experiment modules.



Interior structure of active student SEM experiment.

Side-mounted Hitchhiker-Jr. payloads on orbit.

HITCHHIKER-JR.

The HH-Jr carrier provides mechanical and electrical interfaces similar to the existing GAS carrier, but with a new avionics to provide for better monitoring of carrier functions and improved monitoring and power services for customer equipment if desired. The HH-Jr carrier is designed for Shuttle secondary payloads in canisters.

The HH-Jr carrier system consists of a canister (with or without a motorized door) equipped with a HH Remote Interface Unit (HRIU). The HRIU communicates via the GAS intercom line with a PGSC in the crew cabin. The PGSC is a laptop class personal computer and contains payload unique software provided by SSPPO.

The HH-Jr avionics is operated from Orbiter power unlike the GAS avionics which is battery operated. Orbiter power may also be used for heaters and can be used to operate customer equipment if certain restrictions are met. Customer equipment may also be operated from customer supplied batteries if desired.

During flight operations, the crew controls HH-Jr and GAS payloads using a menu type control and display interface on the PGSC. Unlike the avionics used with GAS, the HRIU reports carrier status information for display to the crew. The status information includes canister temperature and pressure, customer battery voltage and current, door status, and commanded relay status. This information will help SSPPO, the customer, and flight crew make decisions during the flight. On some missions it will be possible to record the status data in the laptop periodically for post flight use. Each HRIU has a unique data bus address allowing the crew to individually communicate with a number of HH-Jr canisters.

If the customer desires and provides the necessary wiring, it is possible to provide the crew with some displays of customer hardware status.

Customer mechanical interfaces are the same as for the standard HH canister. HH-Jr canisters may be flown on the side-mount or bridge configuration.

HH-Jr Electrical Power and Control

HH-Jr customer equipment may be operated from Orbiter power or from internal customer batteries with power switched by carrier relays in a manner similar to GAS.

If internal power is used, the carrier provides two size 12 power wires individually protected by 20 amp fuses in the carrier and switched by a crew controlled relay. Customer peak power should be limited to a maximum of 10 amps in either line because of vacuum derating of the fuses.

The HRIU is provided with a current monitor which measures the total current in all the power lines.

The customer may elect to use Orbiter +28 VDC power. In this case, maximum power draw of the equipment is limited to 100 watts and the energy use over the duration of the mission is limited to a maximum of 4 Kwh. The customer equipment must meet the Orbiter requirements for EMI/EMC. Orbiter power is normally available starting several hours after payload bay doors are opened and extended to several hours prior to payload bay door closing.

The HH-Jr system is capable of providing two control relays which may be used to control customer equipment. The user may select various options including SSPPO supplied temperature sensors to improve crew monitoring of customer equipment, use of carrier analog telemetry inputs for periodic sampling of customer data, and connection to bi-level or pulse command lines to facilitate limited crew commanding of HH-Jr payloads.

Hitchhiker cross-bay bridge configuration on orbit.

HITCHHIKER PROGRAM

The Hitchhiker Program was initiated in early 1984 by the NASA Office of Space Flight with the objectives of providing a quick reaction and low cost capability for flying small payloads in the Shuttle payload bay. Unlike GAS or SEM, Hitchhiker provides standard power, data, and command services, via the Space Shuttle, for customer equipment.

Hitchhiker Carrier Description

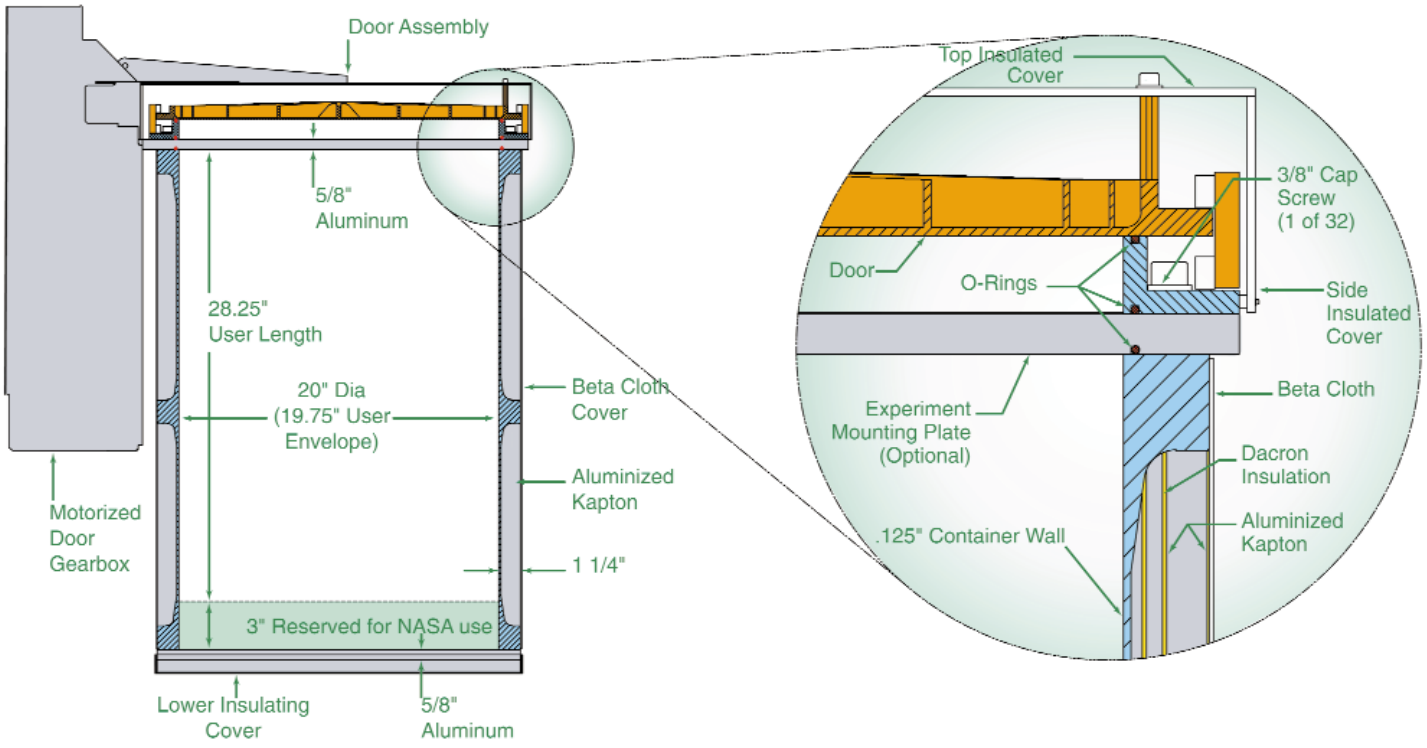
The Hitchhiker carrier system is designed to be modular and expandable in accordance with payload requirements. This flexibility allows maximum efficiency in utilizing Orbiter resources and increases the potential for early manifesting on the Shuttle.

The Hitchhiker carrier system consists of the following elements:

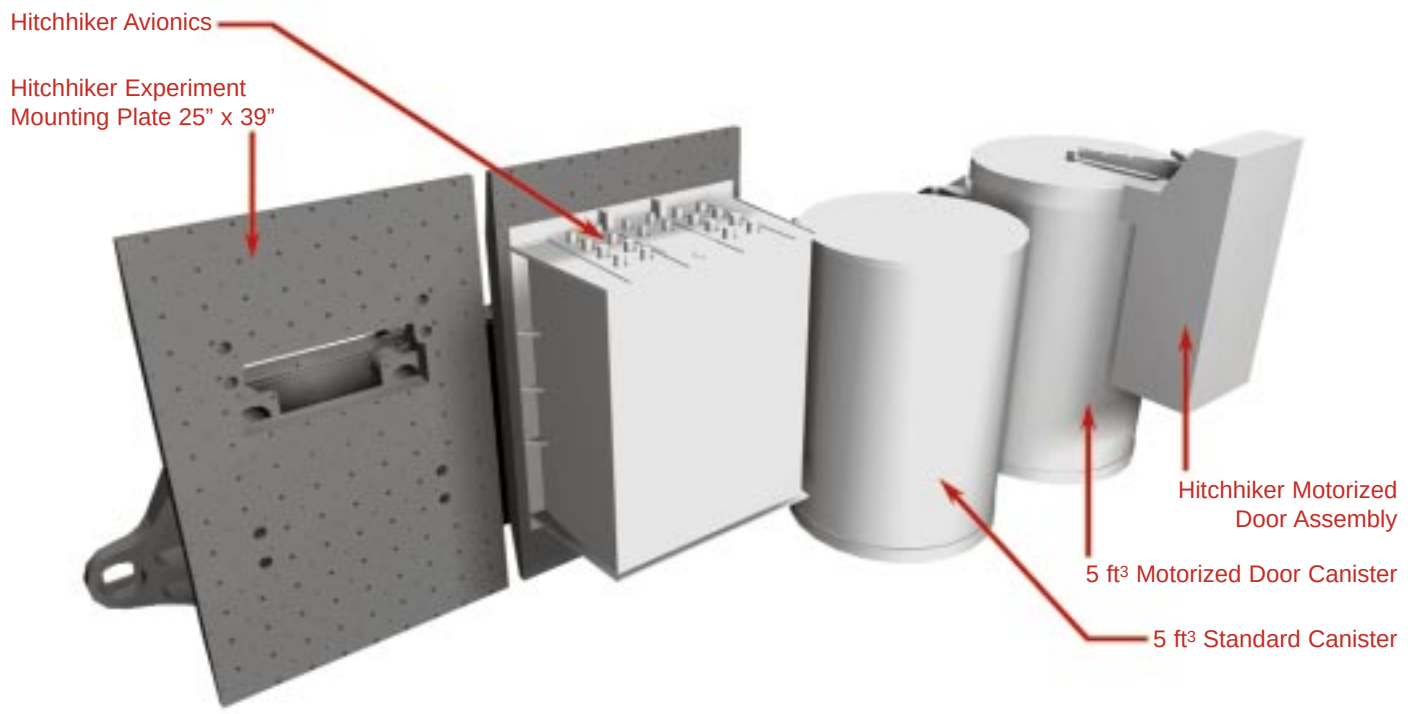
The GAS Adapter Beam is normally used for side-mounted equipment. The beam attaches to the Orbiter longeron and frame structure. The side-mount Hitchhiker system may be installed in Bays 2-8 or Bay 13, port or starboard. The Adapter Beam can hold one canister or mounting plate and the Hitchhiker avionics box, which connects the power, data and signal from the Shuttle to the experiments. Additional Adapter Beams can hold up to 2 canisters, or plates, or one of each, per beam.

The vertical Experiment Mounting Plate provides a 25 by 39 inch mounting surface for up to 200 lbs. of customer hardware. The plate accepts 3/8 inch bolts on 70 mm. centers and can be equipped with heaters, thermostats and thermistors for maintaining and measuring thermal control of the plate and mounted hardware. Plate mounted customer hardware may need additional customer provided blankets, heaters, or other thermal control provisions.

The Hitchhiker Motorized Door Canister has mechanical interfaces nearly identical to a GAS canister and can accommodate a customer payload of up to 160 lbs., 19.75 inches in diameter and 28.25 inches long. Longer canisters may be possible as an optional service. A sealed canister (no door) can also be chosen and will accommodate 200 lbs. of payload in an atmosphere of nitrogen or air.



Hitchhiker Motorized Door Canister



Side-mount Hitchhiker system showing three mounting slots for canisters and/or plates.

The canisters may be insulated or un-insulated depending on the customer’s heat rejection requirements. An un-insulated canister can reject several hundred watts of heat (steady state) under typical conditions and is normally used where the customer requires high power dissipation. Even higher dissipation is possible over short periods separated by cool-down intervals. The customer’s payload must contain heaters and thermostats to maintain the desired temperatures in on-orbit environments.

A Hitchhiker cross-bay carrier can be located anywhere in the payload bay. The carrier structure has mounting slots on its sides which can accommodate up to seven canisters (of Hitchhiker variety) or 25 by 39 inch plates. Four additional mounting slots are located on the top of the carrier and will accept 33 by 27 inch pallets or 33 by 55 inch pallets in any combination with up to 500 lbs. of equipment each. Customer hardware which can be accommodated on the small plate or in a canister can therefore be flown on either side-mount or cross-bay carriers and has the greatest manifesting flexibility.

The HH Avionics Unit provides standard electrical interfaces or “ports” for up to eight customer payloads and is common to both the side-mount and the cross-bay carriers. It contains a microprocessor control unit, relay switching equipment, medium rate multiplexer, and other hardware necessary to interface with the customer hardware and Orbiter. A switch panel in the cabin allows the crew to activate and deactivate the payload and provides an independent command path to control inhibits to any hazardous functions. The crew controlled PGSC laptop may also be used for back up or expanded command and telemetry options.

Each HH Avionics electrical interface consists of a signal cable and a separate power cable which can provide the following services:

- Two 28 V DC (+/- 4 V DC) 10 amp power lines which are turned on (together) by ground command. Customer power and energy are monitored by the carrier system. The maximum simultaneous total customer power for a Hitchhiker is 1600 W and the nominal maximum total customer energy is about 10 kWh/day with additional energy negotiable. Side-mount Hitchhikers

are normally limited to 1300 W and 4 kWh/day.

- Four 28 V bi-level or pulse commands (10 mA max) which can be used with relay drivers and relays to control additional power switching within a payload. For canister payloads, one command is reserved for control of the door.

- An asynchronous 1200 baud uplink command channel.

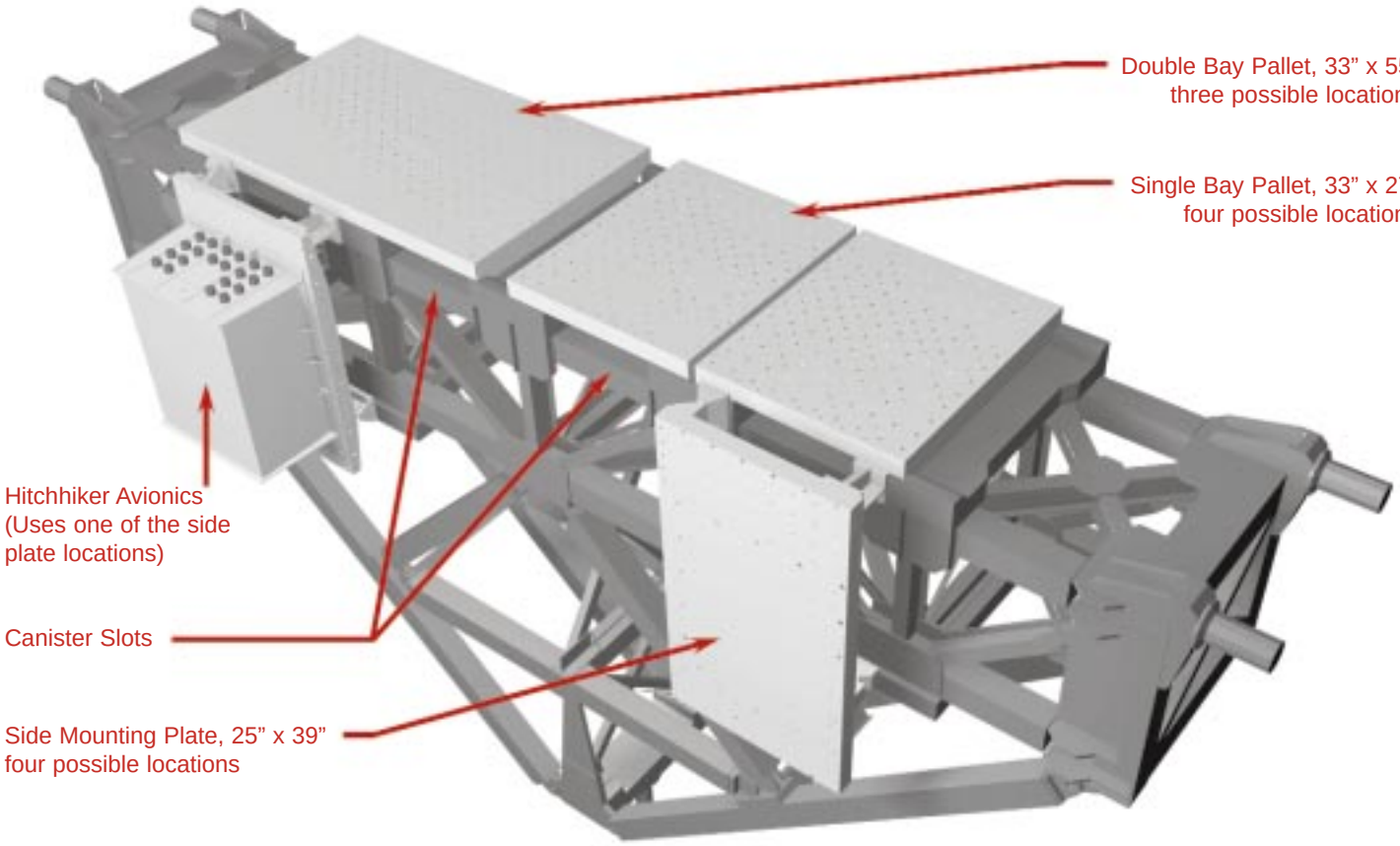
- An asynchronous 1200 baud low-rate down-link data channel. This data is available in real-time up to 85 percent of the time and can also be recorded on-board for later recovery of additional data.

- A medium-rate downlink channel 1-1400 kb/s which can be scheduled for occasional use during the mission. The total simultaneous customer data rate for the Hitchhiker cannot exceed 1400 kb/s.

- IRIG-B format serial time code and a one pulse per minute square wave signal which can be complemented by a time command via the above asynchronous uplink channel.

- Three channels for temperature sensors to allow measurement of payload temperatures even when the payload power is off. For canister payloads, these channels are reserved for door position, canister pressure, and temperature.

- An analog channel, 0-5 V, converted to 8 bit values, 15 hertz sample rate. An index pulse is also supplied which can be used to advance a user supplied analog multiplexer to allow measurement of a large number of parameters.



Hitchhiker-M Mounting Structure

In addition to these standard interfaces, connections can be provided to allow customer use of the Orbiter CCTV system, or crew control and display systems.

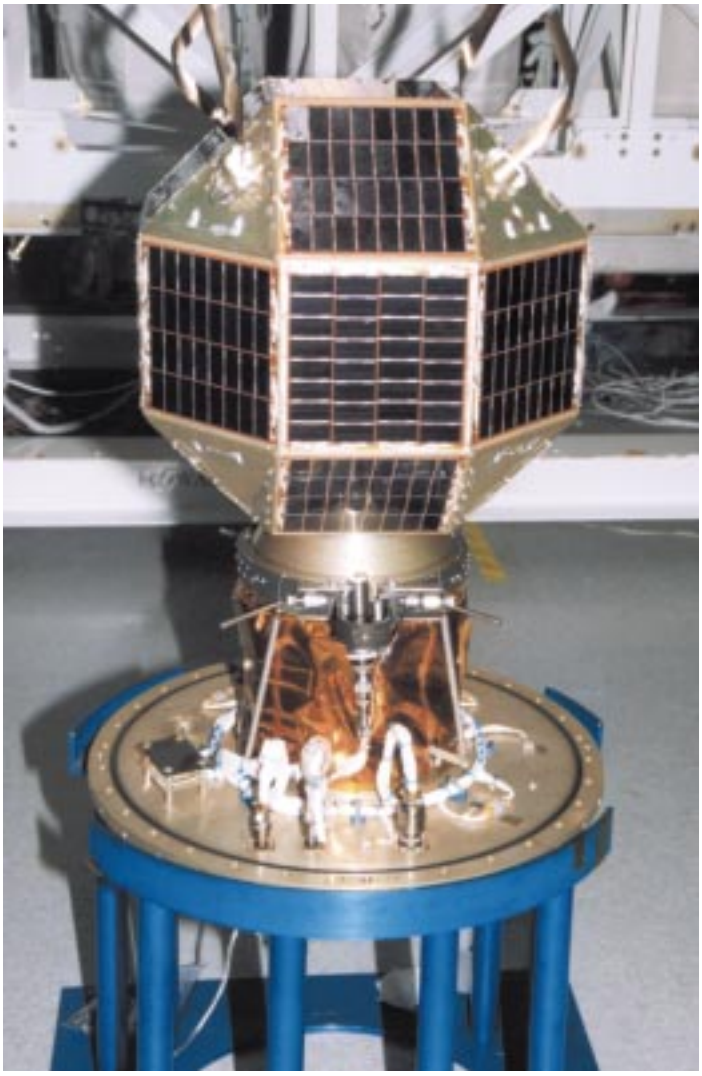
In order to provide low cost, quick reaction, and increased autonomy for the customer, the carrier has been implemented with a transparent data system concept. The Customer provided Ground Support Equipment (CGSE), associated software, and personnel can be used to generate commands to the customer's payload and display data from the payload during payload-to-carrier integration and verification testing, and also during flight operations.

The asynchronous data and command interfaces, and medium-rate data interface are transparent in that the interface between the customer's flight hardware and the carrier is identical in electrical characteristics and protocols to the corresponding interface between the carrier GSE and the CGSE; thus, the GSE the customer used during development of his instrument may be used without modification during carrier integration and flight.

The remaining interfaces (bi-level commands, analog channel, etc.) can also be connected but require conversion to asynchronous format at the CGSE. If desired, the CGSE can also be provided with Orbiter attitude and position data. These interfaces operate in real-time with transmission delays of 5-15 seconds during flight. Simpler experiments with minimal command and data display requirements can be accommodated without customer delivered GSE. All of the downlinked on-orbit data can be made available on CD ROM within one month after the flight.

Hitchhiker Launcher System

The Hitchhiker carrier system provides several options for launching small spacecraft from the Shuttle payload bay. Each option requires the same maximum payload weight and CG offset and same user-supplied 9.37 inch interface plate, which attaches to the carrier with a clamp mechanism. Also, none of the launch configurations provides any electrical power or signal connection to the spacecraft, but each provides a different satellite envelope and payload environment.



PANSAT integration on to PES for Shuttle mission STS-95.

These ejection systems are known as the Hitchhiker Ejection System (HES) and the Pallet Ejection System (PES).

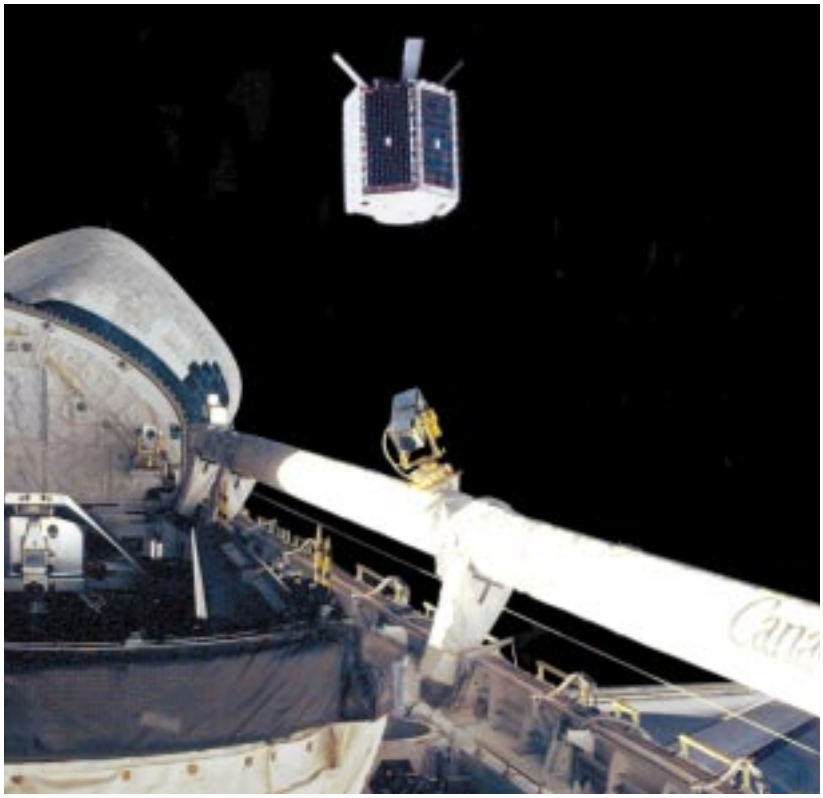
Payload and ejection systems are mounted either in a canister or on a pallet prior to Orbiter installation and launch. The user must provide means for lifting the spacecraft during installation on to the clamp assembly. For a canister-mounted satellite, only the top of the payload will be accessible for servicing after it is installed into the canister.

Once in orbit with the Shuttle in the requested attitude, the clamp is released by the crew and the payload is ejected via a push-plate spring mechanism. The system does not provide for controlled rotation (spin) of the payload prior to ejection, but a worst case ejection torque applied about the ejection vector will be calculated for

every mission. This torque is dependent on several factors. Orbital lifetime of ejected objects in typical Shuttle orbits is usually less than one year.

Spacecraft must be designed to avoid contact with the canister under launch loads or during ejection.

The ejection system and door mechanism are zero fault tolerant against a failure that would cause inability to eject or inability to close the door. Therefore, the spacecraft design must satisfy Shuttle safety requirements for a landing in the Shuttle with the door open. Spacecraft with hazardous functions that occur after ejection (such as deploying appendages) must provide adequate safety inhibits to prevent premature activation. Payloads with such functions are strongly advised to set up a Technical Interchange Meeting (TIM) with the SSPPO system safety organization.



MightySat 1 deployment on Shuttle mission STS-88.

Users may select an ejection attitude and velocity, however, to avoid any possibility of collision with the Shuttle during the portion of the mission following satellite deployment, Johnson Space Center will perform a re-contact analysis to insure that no re-contact occurs.

The Engineer integrates the PAMS Satellite Test Unit on to the HES for Shuttle mission STS-77.

Characteristics of Hitchhiker Launcher Systems

The general characteristics of the HH launcher systems include the following: Maximum spacecraft weight 150 lbs. (68 kg); Maximum spacecraft CG offset from separation plane 10.25 in (26 cm); Maximum spacecraft CG offset from launcher centerline 0.25 in (0.64 cm); Ejection velocity range 1 to 4 ft/sec (0.3 to 1.2 m/sec).

Deviations from the requirements are negotiable on a case-by-case basis. For example, a larger CG offset may be acceptable for a physically smaller satellite.

Future Launch System Development Activities

The SSPPO in conjunction with DoD USAF Space and Missile Systems Center, OLAW, is presently developing a launcher system capable of ejecting up to a 400 lb. payload from the Shuttle cargo bay. Contact SSPPO for more details.

Hitchhiker Manifesting and Programmatics

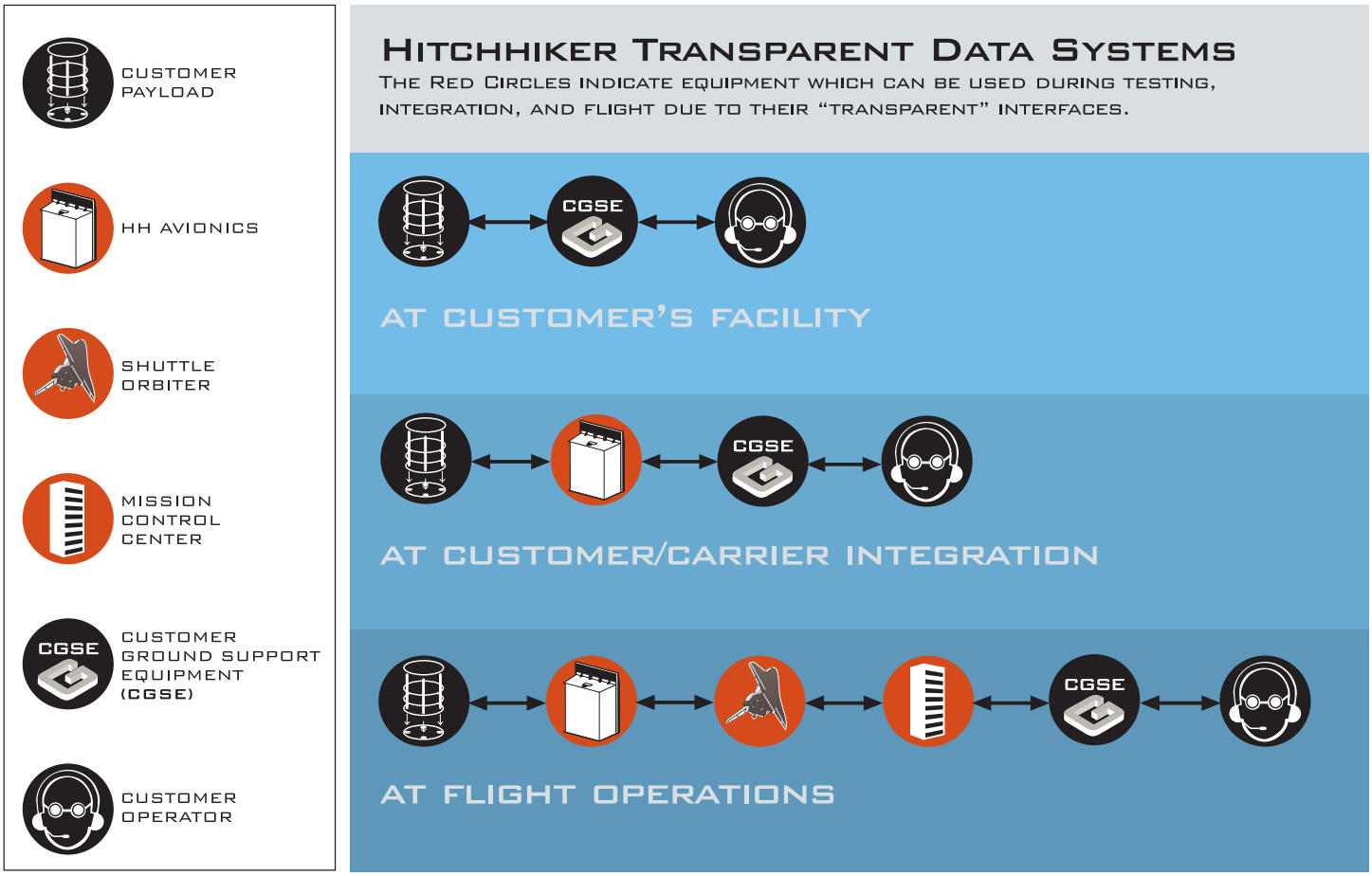
Prospective Hitchhiker customers may first discuss their requirements with SSPPO to determine feasibility and compatibility with Hitchhiker capabilities. A Request for Flight Assignment (NASA Form 1628) is then submitted through the appropriate NASA Headquarters discipline office, and a Customer Payload Requirements (CPR) document to SSPPO. DoD customers should work with the USAF Space and Missile Systems Center, OLAW, to arrange Hitchhiker accommodations.

Prospective reimbursable customers should contact NASA Headquarters Code MO for details on pricing.

Typical Scenario

Ideally, 24 months before flight, the customer delivers preliminary documentation on his payload to GSFC. The safety data package requirements are similar to GAS in the case of canister payloads but are somewhat more complex if the customer's equipment will be plate mounted. About 6 months before flight the customer's hardware is delivered to GSFC and with the help of the customer and his CGSE the payload is integrated to the carrier, and system functional tests and EMI tests are performed. Prior to delivery the customer is responsible for performing any necessary tests required for safety certification (such as static load tests), as well as any tests required by the customer to confirm proper operation (such as vacuum or vibration tests). Following tests at GSFC the integrated payload is shipped to Kennedy Space Center and integrated into the Orbiter where only interface verification tests are performed. Launch occurs typically about 4-10 weeks after Orbiter integration.

During flight, the Hitchhiker is operated from a control center at GSFC with participation of the customers and their CGSE. Displays of orbit position, attitude, ancillary data, and any downlink TV are provided along with monitoring of crew voice transmissions. Following landing the Hitchhiker is removed and de-integrated and the customer hardware is returned to the customer at Kennedy Space Center or GSFC.



Hitchhiker Missions

In January 1986, the Hitchhiker Project flew its first payload, designated the Hitchhiker-G1 payload, on board Space Shuttle mission STS-61C.

As of January 1999, the Hitchhiker Project has flown 58 Hitchhiker experiments. Experiments flown as part of the Hitchhiker Project have included those performing earth and space science research, demonstrations of new technology, proof of concepts, and educational initiatives.

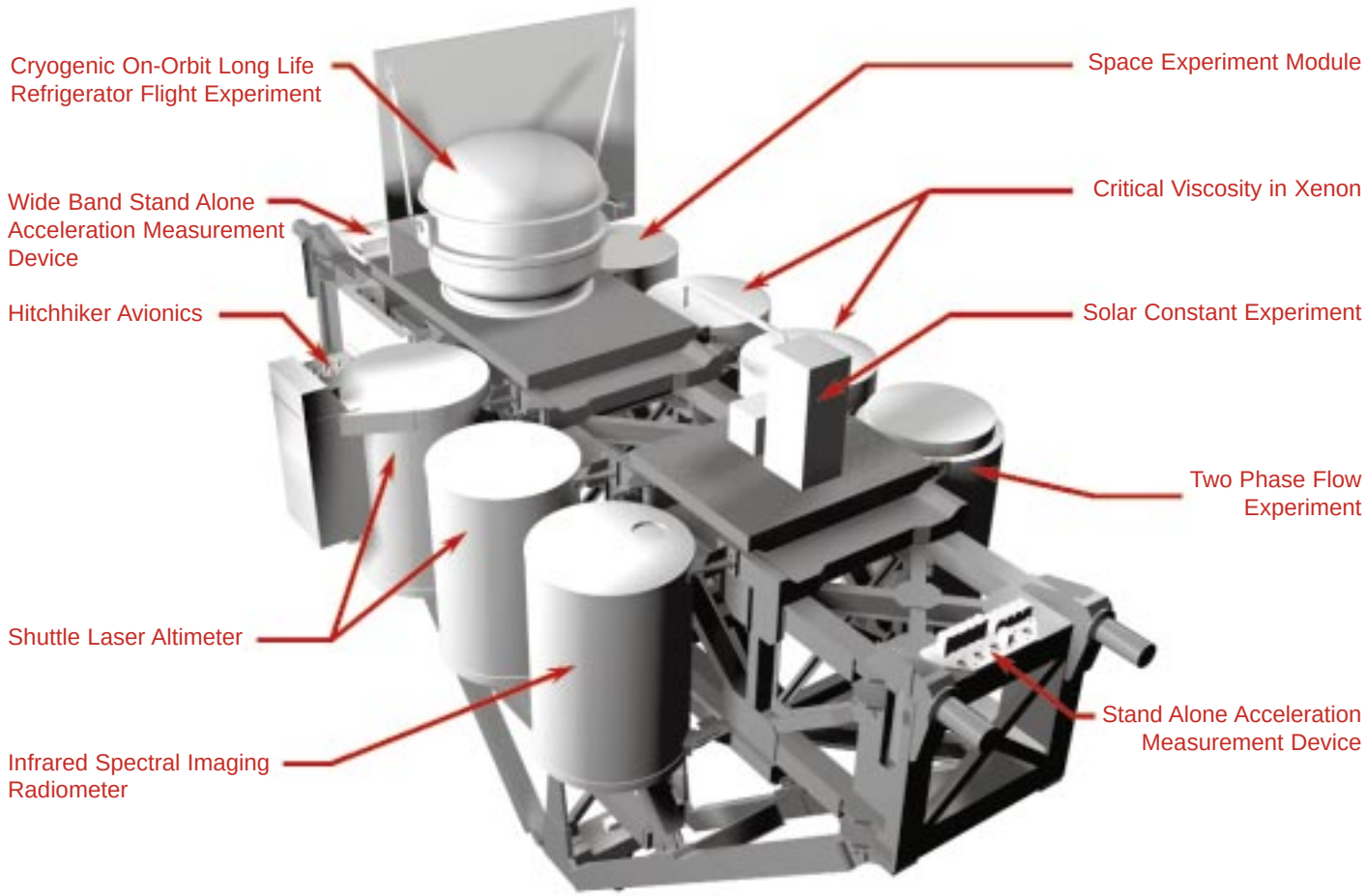
Further Information

Additional information is available via the World Wide Web at: http://sspp.gsfc.nasa.gov.
Or contact:
Shuttle Small Payloads Project Office, Code 870.G
NASA Goddard Space Flight Center
Greenbelt, MD 20771
Phone Number 301-286-8799

Hitchhiker Payload Disciplines

Discipline	NASA Office Code
Office of Space Science	(S)
Office of Space Flight	(M)
Aeronautics and Space Transportation Technology	(R)
Office of Earth Science	(Y)
Life & Microgravity Sciences and Applications	(U)
Office of External Relations	(I)
Office of Human Resources & Education	(F)
DoD (USAF/SMSC, OLAW)	(-)

Payload Carriers Program Office
Code VA-A
Kennedy Space Center
Florida, 32899
Phone Number 407-867-4840



TAS-01 Hitchhiker-M payload complement flown on Shuttle mission STS-85

SSPPO Carrier Comparisons

Comparison of Hitchhiker, Hitchhiker Jr., GAS, CAP and SEM Carrier Requirements

CAPABILITY	HITCHHIKER	HITCHHIKER-JR	SEPARATION SYSTEMS
			HH Ejection System (HES)
			Pallet Ejection System (PES)
Payload Category	Primary/Secondary	Secondary	Secondary
Max Customer Weight (lb.)	3000	200	150
Payload Mounting	Canister; Side Plate Single Bay Pallet (SBP) Double Bay Pallet (DBP)	Canister	HES: Canister (Door/No Door) PES: Canister (Door/No Door); Single Bay Pallet (SBP) Double Bay Pallet (DBP)
Subsystems	PWR, CMD/TLM HTR PWR	PWR, Limited CMD/TLM HTR PWR	No PWR, No CMD/TLM HTR PWR (Canister Walls)
Supplied Power (watts)	1500W	100W	No
Uplink Commands	Yes	No	No
Downlink Data	1.4Mb/s	No	No
Crew Control	Option	PGSC/BIA	SSP
Crew Display	Option	Yes	Yes
Payload Unique Attitudes	Yes	Yes	Yes

Comparison of Hitchhiker, Hitchhiker Jr., GAS, CAP and SEM Carrier Requirements

CAPABILITY	GAS	CAP	SEM
Payload Category	Tertiary	Secondary	Tertiary
Max Customer Weight (lb.)	200	200	6 per module 60 per payload
Payload Mounting	Canister	Canister	Module
Subsystems	No	No	Battery, Fuse Box, Support Structure
Supplied Power (watts)	No	No	600W
Uplink Commands	No	No	No
Downlink Data	No	No	No
Crew Control	3 Relays (APC)	PGSC/BIA	1 Relay (APC)
Crew Display	PGSC/BIA	PGSC/BIA	PGSC/BIA
Payload Unique Attitudes	No	Yes	No